ACCOMPLISHMENT REPORT

PROPULSION DIRECTORATE
November 1999

MICROSATELLITE PROPULSION SYSTEM FABRICATED: MEMS (Micro-Electromechanical Systems) fabrication of the Mark I version of the Free Molecule Micro-Resistojet (FMMR) has been completed. The Propulsion Directorate's Aerophysics Branch (AFRL/PRSA) in conjunction with the MicroDevices Lab fabricated the FMMR at NASA's Jet Propulsion Laboratory (JPL). The FMMR is a micropropulsion system that addresses the need for low mass, low power, efficient, simple, and robust MEMS thrusters to power microsatellites. Microsatellites are extremely lightweight (mass between 1 g and 1 kg) spacecraft envisioned for use in communication/surveillance constellations. Additionally, microsatellites may find application in the performance of failure diagnostic and "mother ship" repair missions. The FMMR device will be capable of thrust levels upwards of 1 mN, and this thrust level is deemed to be adequate to power a microsatellite with a mass as great as 10 kg. Testing of the Mark I FMMR is now underway, and current plans are to fly the FMMR on a microspacecraft from Arizona State University in late 2001. The Mark I version of the FMMR is not optimized for minimum power consumption; however, future versions will account for the minimal power available from potential microspacecraft buses. This unique micropropulsion device currently has an AFRL patent pending. (J. Levine, AFRL/PRSA, (661) 275-6179)
[see image on the next page]

GARSCADDEN HONORED BY UK'S INSTITUTE OF PHYSICS: Dr. Alan Garscadden, Chief Scientist of AFRL's Propulsion Directorate, was recently named a full fellow in the United Kingdom's Institute of Physics. Dr. Garscadden has served in his current position as PR's Chief Scientist since November 1997, and he served as PR's Associate Chief Scientist from January 1995 to November 1997. He serves as technical adviser to the AFRL Commander on a wide spectrum of aeronautical research, including facets of propulsion, aerospace power, hypersonics, laser physics, combustion, and plasma phenomena. He is well known for his research in nonequilibrium plasmas and energized gas flows, lasers, laser-based measurements, plasma-processing of thin films, optical and mass spectroscopic measurements, and electron impact cross sections. During his distinguished career, Dr. Garscadden has authored more than 250 publications and presentations and served on many committees for both national and international meetings and symposiums. Congratulations to Dr. Garscadden for this prestigious honor! (J. Pearce, AFRL/PRO, (937) 255-5451)
[For a detailed biography of Dr. Garscadden, go to http://www.af.mil/news/biographies/garscadden_a.html]

Dr. Alan Garscadden

ENVIRONMENTAL AIRCRAFT BATTERY FOR THE F-16: The Propulsion Directorate's Battery Branch (AFRL/PRPB) accepted the first Environmental Aircraft Battery (EAB) for the USAF on 27 October 1999. The battery is designed as a sealed, maintenance free, and a form, fit, and function (F^3) replacement for the F-16 Pre-Block 40 vented Nickel-Cadmium (VNC) 17 Amp-hour battery. The battery has increased capacity and energy density to meet the More Electric Aircraft Generation II goal of 75 W-h/kg. GRC International, Inc produced the battery through a subcontract with SAFT America, Inc. The bench model battery will be tested to verify performance and capability and to evaluate compatibility with the existing F-16 charger prior to final design modifications of the F-16 demonstration prototype batteries for flight tests. The program to evaluate metal hydride technology was initiated in FY94 with the goal of eliminating environmentally hazardous cadmium and lead (per EPA-17) from aircraft batteries. The B-2, C-17, and Global Hawk UAV program offices have shown significant interest in the technology for potential system upgrades. Recently, the Global Hawk program office initiated a project with PRPB to provide a technology analysis for a battery system upgrade to include metal hydride and lithium-ion battery technologies. (J. Erbacher & R. Marsh, AFRL/PRPB, (937) 255-6241)

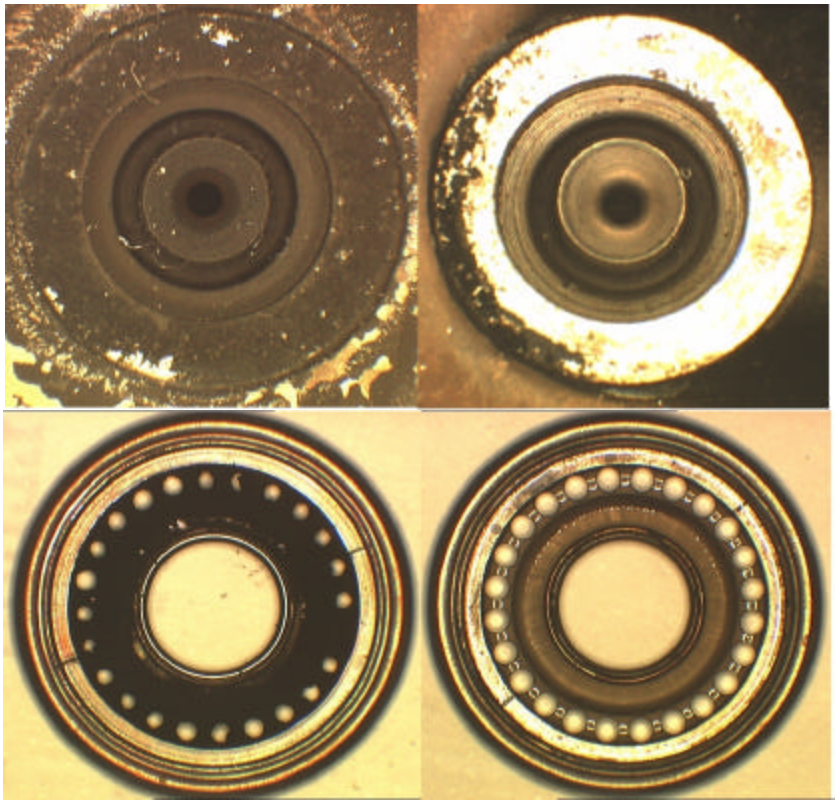
Views of the Environmental Aircraft Battery

AGED MINUTEMAN II ROCKET MOTOR SUCCESSFULLY FIRED: The Propulsion Directorate's Minuteman II test team recently completed the successful firing of an 18-year old rocket motor. The purpose of this static firing was to evaluate the performance of the motor with an eye towards extending the service life of similar motors. The motor fired was an SR-19 solid rocket motor that was formerly used to power the second stage of the Minuteman II ICBM. As a result of this successful firing, service life extension protocols were defined that may extend the service life of SR-19 motors from the same lot by 21 years. At the end of the Cold War, the Minuteman II was decommissioned and 450 SR-19 motors were removed from active duty. There is now considerable interest in using these motors to power launch vehicles for small satellites and targets for national missile defense experiments. The ability to use these surplus motors rather than new motors represents a

tremendous potential cost savings, and this successful testing to examine the service life of these motors is a giant step towards realizing those savings. (L. Perkins, AFRL/PR, (661) 275-6112)

AUSTRALIA EAGER TO IMPLEMENT JP-8+100: Following the results of recent engine testing, the Royal Australian Air Force (RAAF) is eager to adopt the +100 fuel additive for fleet-wide use. The +100 additive was developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) in an effort to minimize maintenance costs associated with fuel degradation within aircraft fuel systems. Added to JP-8 (military) and Jet A (commercial) fuels, +100 has proven to be very effective in a number of military and commercial engine demonstrations. In September 1998, the RAAF performed proof of concept trials of JP-8+100 at RAAF Amberley on an uninstalled TF30 engine, the powerplant for the F-111 fighter/bomber. The results of the RAAF's testing were astounding. After only a minimal test period (~10 hours), visual inspection of critical engine parts showed a tremendous difference in the cleanliness of engines operated on normal JP-8 and those using the additive. Largely based on these dramatic results, the RAAF plans to adopt the additive within the next 18 months. The RAAF is currently exploring avenues to "fast track" implementation of the additive that could result in implementation within 12 months. The United Kingdom, Canada, and New Zealand are also actively investigating the possibility of making the switch to JP-8+100. (P. Liberio, AFRL/PRSF, (937) 255-6918)

The TF-30 Powered F-111



TF-30 Engine Components Run With (right) and Without (left) the +100 Additive

COPENHAVER NAMED ASME FELLOW: Dr. William W. Copenhaver, a Principal Research Aerospace Engineer with the Propulsion Directorate's Turbine Engine Division (AFRL/PRT), was recently named a full fellow of the American Society of Mechanical Engineers (ASME). Dr. Copenhaver has been involved in compression system research for 22 years and has led the Air Force's in-house basic research program on compressor aerodynamics for the past 8 years. He represents the Air Force in basic compression system research throughout the world, and has been requested by many foreign governments to provide seminars on the research efforts under way in his laboratory. He has made significant contributions in the field of compressor aerodynamics related to stall in multistage compressors, shock system unsteadiness, and blade row interactions. In 1988, Dr. Copenhaver won the Propulsion Directorate's highest award for in-house research, the Heron Award. (J. Pearce, AFRL/PRO, (937) 255-5451)

Dr. William Copenhaver

DEMONSTRATION OF A MICRO-CAPILLARY PUMPED LOOP: A research team consisting of the Propulsion Directorate's Power Generation Branch (AFRL/PRPG), the University of California-Berkeley, and the Harris Corporation was recently awarded $3 million from DARPA to develop and demonstrate a micro-capillary pumped loop (micro-CPL). The objective of developing a micro-CPL is to use MEMS (Micro-Electromechanical Systems) technologies for the fabrication of integral cooling into electronic devices. By targeting specific heat sources within electronic devices and taking advantage of high surface-to-volume ratios, integral cooling provides a new stratagem in the thermal management of electronics packages. The DARPA program leverages off of a Ballistic Missile Defense Organization (BMDO) funded technical effort with the University of California-Berkeley to demonstrate the feasibility of the micro-CPL concept. This concept was successfully demonstrated for the first time at the AFRL/PRPG thermal laboratory, and subsequently at the University of California-Berkeley. The tested micro-CPL configurations included an evaporator measuring 400 microns by 1000 microns and approximately 1.5 cm and 2.5 cm in length. Two working fluids, ethanol and water, were used for the tests. The micro-CPL was initially designed at AFRL/PRPG and fabricated of silicon and glass at the University of California-Berkeley. Capillary pumped loop systems are typically several feet in length, so this demonstration of the micro-CPL may represent the smallest tested CPL to date. (K. Yerkes, AFRL/PRPG, (937) 255-6241)

[see image on the next page]

COMMERCIALIZATION OF NOVEL MANUFACTURING PROCESS: Parsons Engineering was recently awarded a contract by the Propulsion Directorate's Propulsion Materials Applications Branch (AFRL/PRSM) to aid in the commercialization of the in-situ densification process. The in-situ densification process is a liquid phase route to producing high-quality, machinable, carbon-carbon composites. Because the carbon matrix precursor is a liquid, the process takes a fraction of the time required by traditional Chemical Vapor Infiltration (CVI) at a fraction of the cost. In order to commercialize the in-situ densification process, a thorough understanding of any potential health hazards associated with the process is required. Parsons Engineering has already begun a thorough evaluation of the process. Four samples of the benzene-rich liquid waste were taken for analysis, and the results indicate that the effluent of the process is minimal and is not an environmental hazard. This testing is an important milestone in commercializing the process. Markets for this technology reside mainly in the aerospace community, but the material can be used in most applications that require materials to retain their strength at high temperatures. Examples of parts that have been manufactured using the process include carbon-carbon for rocket nozzles, aircraft brakes, and fasteners. If the costs of the finished composite can be lowered further, materials manufactured by this process may find markets in consumer products such as sporting goods. (K. Chaffee, AFRL/PRSM, (661) 275-6170)

FORSTER WINS PRESTIGIOUS AWARD: Dr. Nelson Forster of the Propulsion Directorate's Lubrication Branch (AFRL/PRSL) recently received the Alfred E. Hunt Award for best paper of 1998 from the Society of Tribologists and Lubrication Engineers (STLE). He received this award at the American Society of Mechanical Engineers (ASME)/STLE Joint Tribology Conference in Orlando, Florida. This high honor recognized Dr. Forster's work in defining high temperature bearing materials and lubricants for vapor phase lubrication and for increasing basic mechanistic understanding of this new technology. Our heartiest congratulations go out to Dr. Forster for this accomplishment! (R. Wright, AFRL/PRSL, (937) 255-5568)

Dr. Nelson Forster

THERMAL MANAGEMENT PROGRAM MAY AID ADVANCED FIGHTERS: The "Thermal Systems Analysis Tool (TSAT)" Dual Use Science and Technology (DUS&T) Program recently commenced with a kick-off meeting at Wright-Patterson AFB, Ohio. Managed by the Propulsion Directorate's Applications & Assessment Branch (AFRL/PRST), this innovative program will provide the DoD with the ability to assess thermal systems concepts quickly and independently in order to see the "big picture" effects on complete systems. The three industry team members participating in this program are Modelogics, Pratt & Whitney, and ThermoAnalytics. Recent discussions with ASC and the Air Vehicles Directorate (AFRL/VA) suggest that the results of this program may be particularly useful to the F-22 and JSF communities where there are concerns regarding potential thermal problems. Problems that have recently surfaced with these programs were not identified or evaluated during the design stages. Unfortunately, present modeling capabilities cannot address all of the necessary factors for comprehensive system wide evaluations of thermal energy related subsystems; however, the new TSAT

program may provide just such an ability. Consequently, the TSAT program is being seriously considered as a viable methodology for overcoming this shortcoming within the Air Force advanced aircraft community. (V. Van Griethuysen, AFRL/PRST, (937) 255-1234)

MAGNET RESEARCHERS ATTRACTED TO WRIGHT-PATTERSON AFB: On 14 October 1999, the Propulsion Directorate's Power Generation Branch (AFRL/PRPG) hosted an on-site annual review of a Multidisciplinary University Research Initiative (MURI) for developing advanced magnetic materials at Wright-Patterson AFB. The MURI is a cooperative effort principally between Carnegie Mellon University & the University of Delaware, and is managed by the Air Force Office of Scientific Research (AFOSR). The initiative's goal is to develop magnets for tri-service applications with operating temperatures up to 600°C, higher energy products, loss reduction as much as 60 percent, and improved mechanical properties. The conference began with opening remarks by Col Alan Janiszewski, PR's Acting Deputy Director. Technical presentations by several key MURI participants were provided to over 100 attendees representing the DoD service labs, national labs, academia, and aerospace & magnetic materials industries. An evening session followed at the US Air Force Museum's Modern Flight Hangar, with a display of 23 poster stands showcasing much of the nation's cutting-edge research in the areas of hard and soft magnet modeling and simulations, processing methodologies, and characterization techniques. PR's Acting Director, Mr. Richard Quigley, gave a well-received dinner presentation that highlighted the R&D and technology thrusts of the Propulsion Directorate. Using the Air Force Museum to host the conference display session gave a very favorable impression to the attendees, as this allowed a joint demonstration of the Air Force's past accomplishments and its visionary commitment to future research. (R. Fingers, AFRL/PRPG, (937) 255-6241)

Conference Display at the Air Force Museum

David Blasius

BLASIUS NAMED SUPERVISOR OF THE YEAR: David W. Blasius has been named Boss of the Year of ASC's Contracting Directorate (ASC/PK). Mr. Blasius supervises nine individuals as the Branch Chief for Advanced Propulsion and Turbines (AFRL/PRKB) within the Contracting Division of the Propulsion Directorate. The trust and confidence he places in his employees encourages a high level of performance and innovation; consequently, his branch performs at a very high level. The branch completed 99 percent of their FY99 contract awards 1 month ahead of schedule, and all awards were completed on time. Additionally, for a 4-month period, Mr. Blasius served as both the Branch Chief of PRKB and the Division Chief of AFRL/PRK. Despite the pressures of this heavy workload, he still made time to address his employees' needs and concerns. Congratulations on this well-deserved honor! (J. Pearce, AFRL/PRO, (937) 255-5451)

COMBUSTION RESEARCH AIDED BY NOVEL INSTRUMENTATION: A research team led by the Propulsion Directorate's Combustion Branch (AFRL/PRSC) recently achieved a noteworthy feat. Using a newly developed state-of-the-art dual-pump CARS (Coherent Anti-Stokes Raman Spectroscopy) instrument, the team was able to measure four quantities at a point in a combusting flow field simultaneously. Using this optical device, temperature and pressure were measured along with concentrations of carbon dioxide (CO_2) and nitrogen (N_2). The CARS instrument was tested in the PRSC's Atmospheric Combustion Research Facility at Wright-Patterson AFB, Ohio. The researchers involved in this project consisted of personnel from PRSC, Texas A&M University, and Innovative Scientific Solutions, Inc (ISSI). The type of data gathered by this instrument is essential to furthering our understanding of combustion, and it is also invaluable for the development and evaluation of computational models. Furthermore, since this test technique is a non-obtrusive optical method, the measurement does not disturb the flow and alter the data. Further development of the instrument is expected to yield single-shot measurements of six quantities at once: the four quantities measured in this experiment plus concentrations of hydrogen (H_2) and oxygen (O_2). (Capt I. Vihinen, AFRL/PRSC, (937) 255-8623)

LIGHTWEIGHT MATERIAL FOR ROCKET ENGINES: Maxdem Inc has achieved a major success under their Phase I SBIR with the Propulsion Directorate's Propulsion Materials Applications Branch (AFRL/PRSM). In this program, Maxdem is tasked with developing polymeric (i.e., plastic) ducting for use in liquid rocket engines with an emphasis on replacing heavy metallic parts (density ~ 10 g/cm^3) with lightweight plastic materials (density ~ 1.4 g/cm^3). As a baseline, Maxdem is using their trademark Parmax™ polymers which feature superior strength and stiffness. Unfortunately, Parmax™ has a low glass transition (or softening) temperature and it has proven to be difficult to process. A major goal of this effort is to increase the glass transition temperature and improve the processability of Parmax™ via the addition of POSS (Polyhedral Oligomeric Silsesquioxanes). To date, Maxdem has successfully incorporated 7 percent POSS (by weight) into their Parmax™ polymer and as much as 40

percent POSS (by weight) into their polymer resin. This resin can be used as a matrix material in composites, and its exceptionally high modulus is expected to give composites with unprecedented compressive strength. This is a huge step forward, since the most difficult part of POSS nanotechnology is the initial polymer development. (S. Phillips, AFRL/PRSM, (661) 275-5416)

Parmax™ in Liquid Form

Parts Made from Parmax™

DECREASING ROCKET MOTOR VULNERABILITY: Personnel from the Propulsion Directorate's Propellants Branch (AFRL/PRSP) recently conducted propellant sensitivity tests at the Naval Air Warfare Center at China Lake, California. These studies of low-vulnerability propellants provide data essential to determining the safety of propellants. As such, these tests aid in the development of safer solid propellants for rockets and missiles. In the recent testing at China Lake, four propellants were examined: THAAD, a CSD propellant similar to THAAD, and two propellants (LVP-20B & LVP-30M) produced at PR's solid propellant pilot plant at Edwards AFB, California. Tests to simulate bullet impacts were conducted with a 0.75" diameter stainless ball propelled at velocities between 3950 and 3990 feet per second (roughly 2700 mph). Some tests used steel plates to represent the rocket motor case material, while others used fiber phenolic material. A fairly strong explosive response was obtained in all tests using the 0.75" steel ball projectile with the steel case; however, a much weaker response was found for the phenolic case material. This demonstrates the value of composite case materials versus steel for achieving insensitive munitions responses in bullet impact tests. Two additional tests used a 7.62 mm (0.30 caliber) bullet projectile at 2550 ft/sec rather than the 0.75" steel ball to impact the THAAD propellant. In these tests, the steel case material yielded only a minor explosive report, while the composite case material gave an insensitive propellant response (no explosive yield). (C. Merrill, AFRL/PRSP, (661) 275-5169)